Handover Behaviour of Transparent Relay in WiMAX Networks

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***Abstract*-The knowledge on handover behaviour in WiMAX network is essential for network management and planning in order to achieve optimum system throughput. In this paper we have analysed the handover behaviour of transparent relay in several configurations for the IEEE 802.16j Mobile Multi-hop Relay (MMR) WiMAX network. The simulation was performed using NCTUns tool and adopted the hard handover mechanism for three different relay network topologies with varying mobile station speeds. The result shows the handover for internal network is faster than the external network and by appropriate relay deployment the system throughput can be increased up to 14.39%.**

***Index Terms*-WiMAX; Transparent Relay; 802.16j; Hard Handover**

I. Introduction

Handover is a process when a subscriber moves from one connected station to another in the mobility mode. It was crucial mechanism in order to maintain continuous transmission and avoid any signal distortion. In general, there are two main types of handover which are the vertical or heterogeneous handover and horizontal or homogeneous handover. Homogeneous handover happens when a subscriber moves within the same network architecture such as in the same WiMAX (Worldwide Interoperability for Microwave Access) network. While vertical handover will occurs when the subscriber roams from one different network access to another such as from WiMAX to Wi-Fi networks. There are various handover mechanisms available to achieve the maximum quality of service (QoS) in telecommunication industry. The detail is described in the methodology section. IEEE 802.16j standard is for mobile multi-hop relay specification for WiMAX. As the mobile technology advances, multi-hop relay specification for WiMAX is introduced to overcome the demand for coverage extension and capacity enhancement without the need to deploy additional fix backhaul infrastructure. The use of relay in shadowed area or in-building will provide good coverage and can maximize the throughput. The many advantages of the MMR WiMAX approach are less complex in design and construction than the typical base station, lower total system cost, and enabling the rapid deployment. Multiple hops between a Mobile Station (MS) and Base Station (BS) are supported [1]. The components and applications of MMR WiMAX system are as shown in Figure 1 [2].

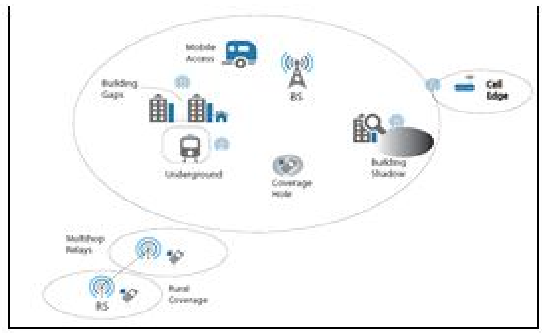

Figure 1: MMR WiMAX components and applications

II. Transparent and Non Transparent Relay

Two different relay modes are defined in the IEEE 802.16j standard [1] which are the transparent and non-transparent relays. Transparent relay is usually deployed to enhance the network capacity while non-transparent relay is used to extend the network coverage. Non-transparent relay does not forward framing information to BS and this mode has lower complexity and operates for maximum of two-hop network topology in the centralized scheduling. The main purpose of non-transparent relay mode is to extend the BS coverage range by generating Relay Station (RS) own framing information to forward the package information from BS to MS. The throughput enhancement is limited and it can operate in more than two-hop relay topology with higher complexity. Two different procedures in resource allocation and scheduling are specified for each relay type. Transparent relay mode will be scheduled by BS (centralized) and non-transparent relay mode is scheduled either by BS or RS (distributed) [3]. The success of a good mobility framework largely depends on the capability of performing fast and seamless handovers irrespective of the deployed architectural scenario [4]. The next section will discuss some recent proposal on handover from various factors.

III. Previous Work

This section discusses few recent works on handover approaches. For vertical handover between WiMAX and WLAN, authors [5] have proposed the scheme which allocates Mobile Agent Identifier as the authentication, authorization and accounting (AAA) key during the initial connection establishment in WiMAX or WLAN. The same

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architecture was also explored by [6] using hybrid technique where both the operator and user satisfaction are considered. The result from both approaches show lower handover latency is achieved as compared to the existing technique. To evaluate the proposed algorithm, which is based on multi-criteria evaluation and analysis can be performed using the network simulator [6].

Self-Optimization Handover Mechanism [7] which uses Global Positioning System (GPS) can navigate the system and combine with the mobility characteristics of mobile RS as the basic concept in Self-Optimization of Organic Computing of the mechanism. By using this mechanism, a BS can be planned in advance for the path choice. To reduce the number of handover, the channel is scanned to provide a more stable WiMAX services. Authors [8] designed an RS grouping algorithm to minimize handoffs by utilizing greedy grouping policy; RS pairs with higher handoff rates will have higher priority for selection. The simulation result shows that the handoff frequency of the considered MR network can be significantly be reduced, and the suitable RS grouping patterns can be derived using their grouping algorithm.
While [9] introduced a new fast handover scheme that able to maintain a stable data transmission and outperform the conventional method.

A few analysis was carried out as in [10] and [11] for the behaviour of handover in Mobile WiMAX environment. The critical parameters considered are values of the contention window minimal and maximal size, number of transmission allocations per frame, number of available CDMA ranging codes, timers and maximum retransmission limits used in the processes of ranging, basic capabilities negotiation and registration. In addition [11] introduced the reduction of handover delay for certain noise levels by introducing a continuous scanning process. Another evaluation from [12] using association and handover optimizations through BS-to-BS signalling the network re-entry time can be significantly shortened. However, the throughput analysis shows that association has only small effect on throughput; the Mobile IP tunnel establishment was found to be the major contributor.

The National Chiao Tung University – network simulator (NCTUns) module has implemented hard handover using the corresponding weight of each link connection. In our study, the behaviour of hard handover of transparent relays in WiMAX network for the RS – BS – BS – RS configurations will be analysed.

IV. Methodology

In this research, we adopt the free based simulator that supports relay architecture (IEEE 802.16j) from NCTUns tool. It provides real-life simulation with re-entering kernel method and come with friendly user graphical interface (GUI) suites for beginners [13].

The WiMAX topology was constructed as shown in Figure 2 for transparent relay types to investigate the effect of handover on throughput for various configurations comprising of two BSs and three RSs with MS7 roaming with various speeds travelling from RS5 cell to RS6 cell coverage. Initially MS7 is connected to BS3 through RS5 and will moves from RS5 towards RS6. Three different relay network configurations are considered for three scenarios A, B and C.

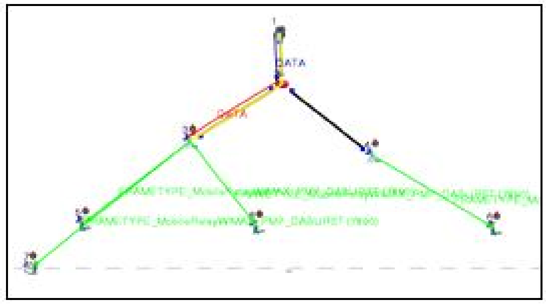

Figure 2: Topology drawn to observe the handover between two networks

In order to match the OFDMA standard [1],[3] the WiMAX system model was being set up according to OFDMA parameters such in Table I.

TABLE I: Ofdma Parameter Used

OFDMA Parameters	Value
FFT-size	1024
DL subcarriers allocation	30
UL subcarriers allocation	35
Bandwidth	10 MHz
Sampling factor	28/25
Sampling frequency	11.2 MHz
CP ratio	1/8
CP time	11.425 us
Symbol time	102.825 us
Frame duration	5 ms
Physical slot	0.357143 us
TTG / RTG	90 PS

A. Types of Handover

There are three types of handover mechanism as stated in IEEE 802.16j standard, namely the hard handover, macro diversity handover (MDHO) and fast base station switching (FBSS) [14],[15]. Since the hard handover is mandatory while MDHO and FBSS are optional, the current public domain NCTUns tool only supports hard handover mechanism. The hard handover mechanism employs the principle of break-before-make. MS will break the connection with the original BS before making a new connection with another BS. Although it may lower the handover quality, the MS need not maintain a list of BSs and waste the radio resources. Figure 3 shows the hard handover mechanism.

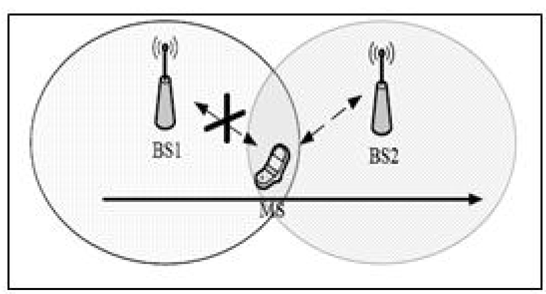

Figure 3: Mechanism of hard handover [15]

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B. MS Path Selection Algorithm

To decide and assign the access station for a MS, NCTUns module implements a path selection algorithm by assigning weight for each link connection. The BS decides the MS's access station according to the weight of the link between the MS and RS and the weight of the link between the RS and BS. The weight of the link corresponds to the modulation and coding rate used on that link for the required coverage as shown in Figure 4 which proportional to distance from the BS. The BS will choose to use the RS as the MS's access station if the following condition is satisfied:

$$Wr + Wp < Ws$$

where,

Ws: the corresponding weight of MS to BS's uplink
Wr: the corresponding weight of MS to RS's uplink
Wp: the corresponding weight of RS to BS's uplink

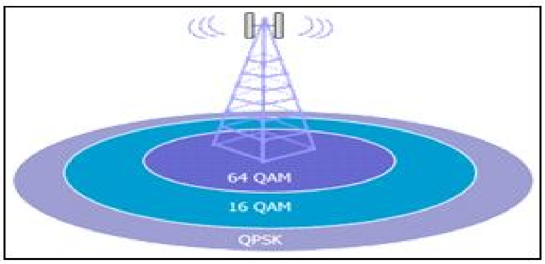

Figure 4: Relationship between Modulation, Coding and Coverage.[11]

The speed of MS is also varied and MS7 is set to 5 m/s, 10 m/s, 15 m/s, 20 m/s, 25 m/s and 30 m/s as to observe the effect of different mobility speeds on handover latency and on network throughput.

V. Result And Discussion

The results obtained through NCTUns simulations by recording the corresponding weight of each MS position per second. Each connection weight is compared and the lower weight is selected by BS as the communication link. The bandwidth is set to 50 Mbps with MS7 moved at 10 m/s speed or 36 km/j. Host1 transmits the data from 3 to 120 seconds to MS7 and the path link selection is determined by the BS. Figure 5 shows the recorded weight for RS5, RS8 and BS3 for the first 80 seconds. At starting point, MS7 is connected through RS5 since it has the lowest weight compared to BS3 and RS8. Furthermore the location of RS5 is the nearest to MS7. When MS7 moves from RS5 towards RS6, the recorded weight of RS5 will be increasing. When the weight of direct access BS3 is less than RS5, then the connection will handoff to link BS3. From the graph, the handoff of MS7 to BS3 by RS5 occurs at the 29th seconds.

MS7 is served by BS3 about four seconds before handover the connection to RS8. Starting from 33rd seconds to 77th seconds MS7 is being connected through RS8. It is because MS7 is moving towards RS8 and the weight decreases. At the 77th seconds, MS7 is handoff to BS3 since the coverage of BS3 is higher than RS8 before passing MS7 to neighbouring network, BS4 through RS6. Overall, the

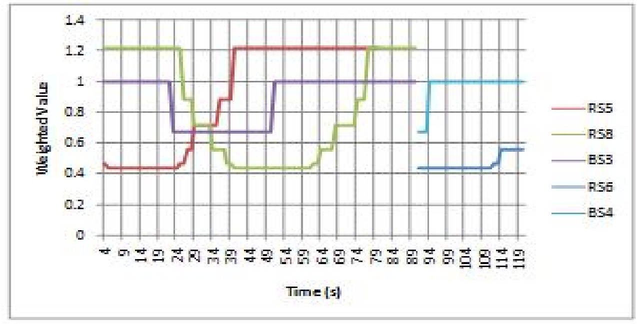

Figure 5: Graph of handover based on weighted value

process of path link selection or handover is based on the corresponding weight of each connection. The handover time to transfer from BS3 to BS4 is about 0.3388 ms for all speed as shown in Figure 6 below. The different is very small. This result is also supported by [16] and [17] which have small changes while the speed or velocity increases.

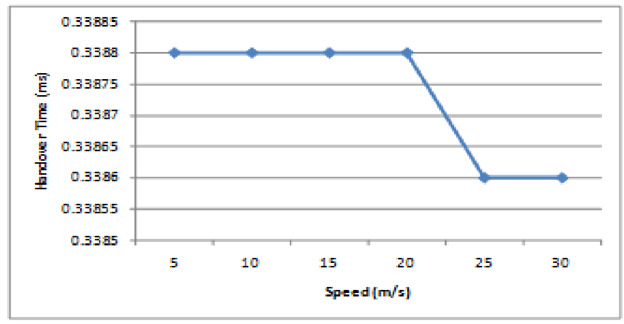

Figure 6: Graph of handover time based on speeds

Simulation is also performed to study the effect of handover on throughput for the downlink transmission. The handover behaviour for BS to RS and from RS to another BS connection is observed in order to compare their performance.

The system model employs the 16QPSK ¾ modulation with 18 bytes slot size for 620 available slots in downlink transmission with a frame duration of 5ms [15]. The theoretical throughput can be calculated by using the following equation [18].

$$\text{Throughput} = \frac{\text{Slot size (bytes)} * \text{Number of slot}}{\text{Frame duration}} \quad (1)$$

$$= \frac{18 \text{ bytes} * 620 \text{ slots}}{5 \text{ ms}}$$

From (1) the maximum throughput computed is 17.86 Mbps for downlink transmission over the IEEE 802.16j environment. Host1 sends data continuously to MS7 from 3rd to 120th seconds. Figure 7 shows the graph of throughput received by MS7 while moving from originally connected RS5 to BS3 then to RS8 and finally handover to RS6.

Three different RS placements or topologies were deployed to observe the effect on handover. The first topology is as shown in Figure 2 where RS8 is the intermediate RS between BS3 and BS4 and was set up as subnet of BS3. This topology is referred as Scenario A. Another topology is Scenario C with RS8 being the subnet of BS4. The last Scenario B does not have RS8 between BS3 and BS4 as the controlled

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simulation. All the throughputs were plotted in the same graph to facilitate for comparison purposes.

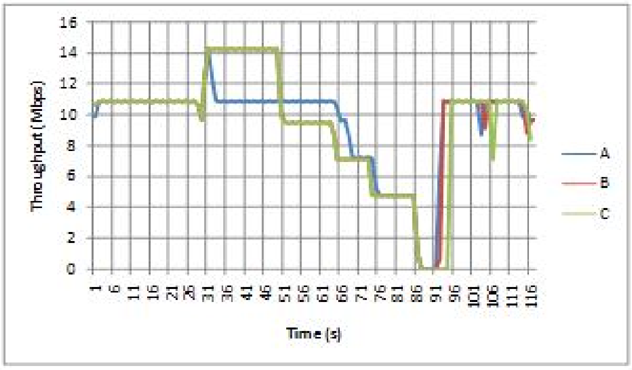

Figure 7: Graph of throughput for MS7 for scenario A, B and C

As the first handover occurs on 29th second when the transmission of MS7 changes from RS5 to BS3, it causes higher throughput transition and no data lost during this handoff. There is no different in throughput performance for the initial stage for all scenarios but after a few seconds, Scenario A throughput begins to drop as it was being handoff to RS8. While Scenario B and C still maintain at high throughput until it being handover to BS3 at the 50th seconds. For this second handover, the throughput drops rapidly since MS7 is moving away from BS3.

For Scenario A, MS7 has RS8 to enhance its throughput and is able to maintain it until the 77th seconds. After that for all scenarios MS7 is being served by BS3 until it being transferred to BS4 network. During the process of hard handover between two networks, the throughput drops until zero and no data received by MS7. With the aid of RS8, Scenario A has fewer periods of zero throughputs and after that all scenarios show the throughput to increase as usual while connected to BS4 network.

The observation on the effect of different mobile speed on throughput is as in Figure 8 and Figure 9 when using topology as in Scenario A. With different speed, the MS7 handover occurs at different time. The faster the speed the earlier the handover occurs. Two graphs are drawn for convenient to evaluate them since it have different speed range. The simulation run for 5 m/s mobile speed is extended to the 200 seconds simulation since the handover occurs at the 174th seconds. The slower the mobility speed, the observed throughput is more stable.

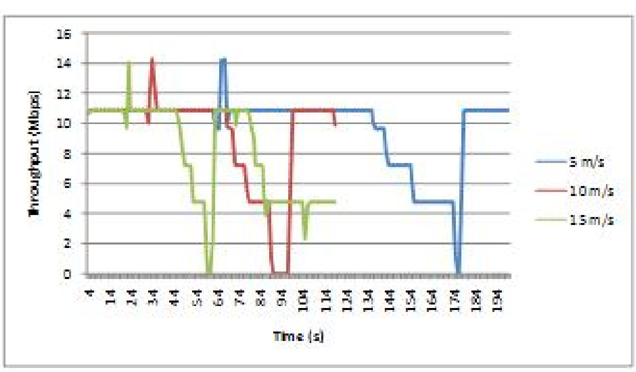

Figure 8: Graph of throughput for different speed of MS7

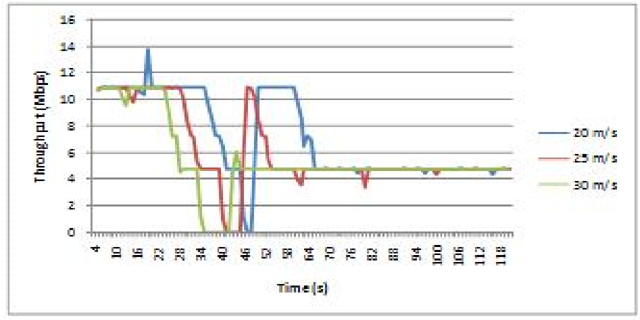

Figure 9: Graph of throughput for different speed of MS7

The simulation of the handover process for transparent relay mode indicates that for within the same network or cell, the handover occurs smoothly without affecting much of the throughput. However the network throughput decreases during the hard handover for different networks due to losses of few packets. Even though the time of handover process is about 0.3388 ms, the change of path link causes the break in transmission during that short period. The deployment of intermediate RS as in Scenario A is able to increase the system throughput up to 14.39%. As stated in [19] the handover failure will increase when the velocity of MS increases, thus the implementation of RS will helps the situation to minimize the failure.

Another factor which affects the signal loss is the system path loss which also influences the process of handover. In this simulation study, the Cost Hatta propagation path loss model is used to simulate the WiMAX propagation for large coverage area.

VI. Conclusion & Future Work

This paper has presented the throughput of MMR WiMAX network which can be enhanced through the appropriate relays deployment. The simulation result shows that transparent relay is capable to increase the throughput by 14.39%. The handover time in the same network or cell coverage does not affect the throughput however for inter-cell handover the vendor has to plan well in advance for the appropriate deployment of the MMR WiMAX BS and RS's for optimum system performance. The suitable placement of intermediate RS is necessary to minimise the effect of packet loss or latency due to handover. With higher MS mobility speed, the probability of handover to occur is decreased and thus proper planning and network implementation is needed to avoid data losses or an enhancement of system is required.

The selection of relay types and modes is also crucial in the management of fairly connected network for maximum system throughput. Thus for future research work it can be expanded to consider the effect of scheduling of several MS, directional antenna, path selection or frequency reuse in specific topology on the overall system throughput.

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